

3. Bioacoustic survey; submitted by Jennifer H. Emery (Leg II), Roger P. Hewitt (Legs I and II), David A. Demer (Leg I) and Dale Roberts (Legs I and II).

3.1 Objectives: During Leg I a multinational effort sponsored by CCAMLR was undertaken to estimate the krill (*Euphausia superba*) standing stock in the Scotia Sea by conducting both large-scale and meso-scale acoustic surveys (see Report of the Bo workshop, SC-CAMLR-XIX, 2000, CCAMLR, Hobart, Australia). The primary objectives during Leg II were to map the meso-scale dispersion of krill in the vicinity of the South Shetland Islands; to estimate their biomass; and to determine their association with predator foraging patterns, water mass boundaries, spatial patterns of primary productivity, and bathymetry. In addition, efforts were made to map the distribution of myctophids and determine their relationship with water mass boundaries and zooplankton distribution.

3.2 Methods and Accomplishment: Acoustic data were collected using a multi-frequency echo sounder (Simrad EK500) configured with down-looking 38, 120, and 200 kilohertz (kHz) transducers mounted in the hull of the ship. System calibrations were conducted before and after the surveys using standard sphere techniques while the ship was at anchor in Stromness Bay, South Georgia and Admiralty Bay, King George Island. During the surveys, pulses were transmitted every 2 seconds at 1 kilowatt for 1 millisecond duration at 38kHz, 120kHz, and 200kHz. Geographic positions were logged every 60 seconds. Ethernet communications were maintained between the EK500 and two Windows NT workstations. Both Windows NT workstations were running SonarData EchoLog and EchoView software. One unit was used for primary system control, and data logging, processing and archiving while the other ran in parallel for back-up logging and archiving.

Leg I (CCAMLR Synoptic survey)

An acoustic survey of the Scotia Sea was conducted on Leg I. This survey was divided into two large-scale and two meso-scale areas (see Figure 2): (1) a 473,318 km² area north of the Antarctic Peninsula sampled with three northwest-southeast transects; (2) a 1,109,789 km² area of the Scotia Sea beginning north of South Georgia sampled with three north-south transects; (3) a 24,409 km² area north of the South Orkney Islands sampled with four north-south transect; and (4) a 25,000 km² area on the north side of South Georgia sampled with four north-south transects. It should be noted that the two large-scale surveys included a total of 19 transects (Antarctic Peninsula) and 10 transects (Scotia Sea) with the remaining transects completed by other CCAMLR participants (Report of Bo workshop, SC-CAMLR-XIX, 2000, CCAMLR, Hobart, Australia).

Leg II (Survey D)

An acoustic survey of the waters surrounding the South Shetland Islands was conducted on Leg II. This survey was divided into three areas (see Figure 4): (1) a 41,673 km² area centered on Elephant Island (Elephant Island Area) was sampled with nine north-south transects; (2) a 34,149 km² area along the north side of the southwestern portion of the South Shetland archipelago (West area) was sampled with seven transects oriented northwest-southeast; and (3) a 8,102 km² area south of King George Island in the Bransfield Strait (South area) was sampled with three transects oriented northwest-southwest.

Two methods of krill delineation for estimating biomass were used: (1) the visual classification method (Leg II) and (2) the two frequency method (Legs I and II). These methods were also used for myctophid delineation on Leg II.

Visual Classification Method

This method involved visual comparison of scattering layers at the three different frequencies.

Three main rules were applied for krill classification:

- (1) Aggregations that were horizontally continuous and contained well-defined edges when above 250m were classified as krill.
- (2) Continuous aggregations with less defined edges found below 250m during daylight hours were classified as krill if intensity was highest at 200kHz and lowest at 38kHz.
- (3) At dawn and dusk, dense vertically continuous aggregations most intense at 200kHz and least intense at 38kHz were classified as krill.

A conservative approach was used to classify the structures of the aggregations as krill and, as such, a bias may exist toward underestimation of krill biomass density based on visual classification of this data.

Myctophid visual classification was based on the following rules:

- (1) Aggregations that were equally or more intense at 38kHz than at 120kHz and 200kHz were classified as myctophids.
- (2) Small, dense, and slightly vertically elongated swarms forming a horizontal chain of scatterers were classified as myctophids.
- (3) Continuous horizontally elongated scattering layers lacking well defined edges, with a cloud-like appearance were classified as myctophids if most intense or equally intense at 38kHz. These layers were usually much more dispersed than krill swarms.

Two Frequency Method

Past research has focused on the delineation of krill using a Δ MVBS (mean volume backscattering strength) window of 2-12dB, where Δ MVBS (dB) = MVBS 120kHz – MVBS 38kHz (Madureira *et al.*, 1993). However, recent studies have shown that the 2-12dB window omits a considerable amount of smaller krill (Watkins and Brierley, 2000). Therefore, it was decided during the CCAMLR Bo workshop that a range of 2-16dB would be more appropriate. This method was then employed for acoustic data from both Legs I and II.

Although this approach is more objective than the visual classification method, it is also more liberal because of the window range. Some bias may exist for slight overestimation of krill biomass density. The 2-16dB window allows smaller krill to be included in the analysis, but it may also allow the smaller euphausiid species to be included as well.

A window of –5 to 2dB was applied to the two frequency method for the purpose of delineating myctophids. This range was chosen based on observed differences in myctophid backscattering values between 38kHz and 120kHz. The results were compared with the visual classification of myctophids and found to be nearly identical.

Abundance Estimation and Map Generation

Backscattering values were averaged over 5m by 100s bins. Time varied gain (TVG) noise was subtracted from the echogram, and in the case of the two-frequency method, the Δ MVBS window was applied. TVG values were based on levels required to erase the rainbow effect plus 2dB. The remaining volume backscatter classified as krill or myctophids was integrated over depth (500 m) and averaged over 1852.0m (1 nautical mile) distance intervals. These data were processed using SonarData Echoview software.

Integrated krill volume backscattering strength per unit sea surface area (S_A) was converted to estimates of krill biomass density (ρ) by applying a factor equal to the quotient of the weight of an individual krill and its backscattering cross-sectional area, both expressed as a function of body length and summed over the sampled length frequency distribution for each survey (Hewitt and Demer, 1993):

$$\rho = 0.249 \sum_{i=1}^n f_i(l_i)^{-0.16} S_A \quad (\text{g/m}^2)$$

Where

$$S_A = 4\pi(1852)^2 \int_0^{500} S_v \quad (\text{m}^2/\text{n.mi.}^2)$$

And f_i = the relative frequency of krill of standard length l_i .

For each area in each survey, mean biomass density attributed to krill and its variance were calculated by assuming that the mean density along a single transect was an independent estimate of the mean density in the area (Jolly and Hampton, 1990).

No myctophid biomass estimates were made because of the lack of target strength data and length frequency distributions. The nautical area scattering coefficient (S_A) attributed to myctophids was integrated using SonarData EchoView software and then used to map their distribution.

3.3 Tentative Conclusions: During survey D, the highest concentration of krill was mapped east of Elephant Island between Elephant Island and Clarence Island (Figure 3.1). High concentrations of krill were also found northeast of King George Island/southwest of Elephant Island and along the shelf break north of the South Shetlands, with a high density pocket along the shelf northeast of King George Island. Krill scattering layers were typically found between 50m and 250m. Similarities and differences in krill density estimates between the two methods

can be observed both visually and numerically (Figure 3.1, Table 3.2) Visual comparison of echograms indicated that these differences may be attributed to the inclusion of smaller euphausiid species by the two frequency method, or the exclusion of smaller, more dispersed, *E. superba* by the visual classification method. However, no small *E. superba* were collected in the net samples. The two-frequency window was thus set at 2 to 12db. In spite of this change, the results were consistent with the previous two-frequency analysis.

Mean krill biomass densities within the eight years of the AMLR surveys were highest in 1997 and lowest in 1999. The 2000 survey results indicate a slight increase in krill density since 1999 (Table 3.1) and a model of the variability of acoustic estimates of krill in the Elephant Island area predicts increasing krill density in 2001 (Figure 3.4, Hewitt and Demer, in press).

Scatterers attributed to myctophids were found seaward of the shelf break. Areas of highest myctophid backscattering volume were mapped northeast of Elephant Island, northwest of King George Island, northwest of Livingston Island, and due north of the eastern edge of King George Island (Figure 3.2). Myctophids were found predominantly at depths greater than 150m.

Myctophid aggregations of greatest volume backscattering were found on transect 6 of the West area and transect 7 of the Elephant Island area. Cross sectional representation of these scattering layers and sea water temperature indicates a relationship between the myctophids and the Circumpolar Deep Water (Figure 3.3). These aggregations are typically found between approximately 1.5 and 2.0 °C at the boundary between cold winter water and the deeper, but warmer, Circumpolar Deep Water.

There appeared to be little indication of krill/myctophid interaction. Few areas of overlap between the two occurred and where they did, krill were detected at more shallow depths than myctophids.

3.4 Disposition of Data: All integrated acoustic data will be made available to other U.S. AMLR investigators in ASCII format files. The analyzed echo-integration data consume approximately 10 Mbytes. The data are available from Jennifer H. Emery, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037; phone/fax – (858) 546-5609/546-5608; e-mail: jhemery@ucsd.edu

3.5 References:

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Survey	Area	Mean Density (g/m ²)	Area (km ²)	Biomass (10 ³ tons)	CV %
1992 A (late January)	Elephant Island	61.20	36,271	2,220	15.8
D (early March)	Elephant Island	29.63	36,271	1,075	9.2
1994 A (late January)	Elephant Island	9.63	41,673	401	10.7
D (early March)	Elephant Island	7.74	41,673	323	22.2

1995 A (late January)	Elephant Island	27.84	41,673	1,160	12.0
D (early March)	Elephant Island	35.52	41,673	1,480	24.2
1996 A (late January)	Elephant Island	80.82	41,673	3,368	11.4
D (early March)	Elephant Island	70.10	41,673	2,921	22.7
1997 A (late January)	Elephant Island	100.47	41,673	4,187	21.8
1998 A (late January)	Elephant Island	82.26	41,673	3,428	13.6
	West	78.88	34,149	2,694	9.9
	South	40.99	8,102	332	16.3
D (late February)	Elephant Island	47.11	41,673	1,963	14.7
	West	73.32	34,149	2,504	16.6
	South	47.93	8,102	388	12.2
1999 A (late January)	Elephant Island	23.72	41,673	988	20.3
	West	27.13	34,149	927	28.7
	South	19.68	8,102	159	9.4
D (late February)	Elephant Island	15.37	41,673	641	26.0
	West	11.85	34,149	405	30.0
	South	N/A	8,102	N/A	N/A
2000 D (late February)	West	37.54*	34,149	1,282	14.1
	Elephant Island	36.19*	41,673	1,508	21.1
	South	22.75*	8,102	184	29.2

Table 3.1 Mean krill biomass density for surveys conducted from 1992 to 2000. Coefficients of variation (CV) are calculated by the methods described in Jolly and Hampton, 1990, and describe measurement imprecision due to the survey design. 1993 estimates were omitted due to system calibration uncertainties; only one survey was conducted in 1997; 1999 south area values are not available due to lack of data. See Figure 1 in the Introduction Section for description of each survey.

*Data values are based on the two-frequency krill delineation method.

Elephant Island Area			
		visual	2-16dB window
	n	krill density	krill density
Transect 1	111	9.22	38.04
Transect 2	118	55.85	59.46
Transect 3	116	13.11	14.71
Transect 4	109	38.29	48.52
Transect 5	128	7.16	15.61
Transect 6	126	33.95	73.56
Transect 7	125	42.37	49.91
Transect 8	115	19.42	22.73
Transect 9	112	2.05	10.40

South Area			
		visual	2-16dB window
	n	krill density	krill density
Transect 1	20	0.34	1.51
Transect 2	44	30.53	31.06
Transect 3	40	26.28	24.21

West Area			
		visual	2-16dB window
	n	krill density	krill density
Transect 1	41	52.09	71.07
Transect 2	40	33.72	32.21
Transect 3	66	30.09	38.33
Transect 4	71	37.86	40.60
Transect 5	73	28.70	32.73
Transect 6	89	28.73	44.77
Transect 7	99	7.47	20.13

Table 3.2 Krill density estimates by area and transect for Survey D, Leg II.

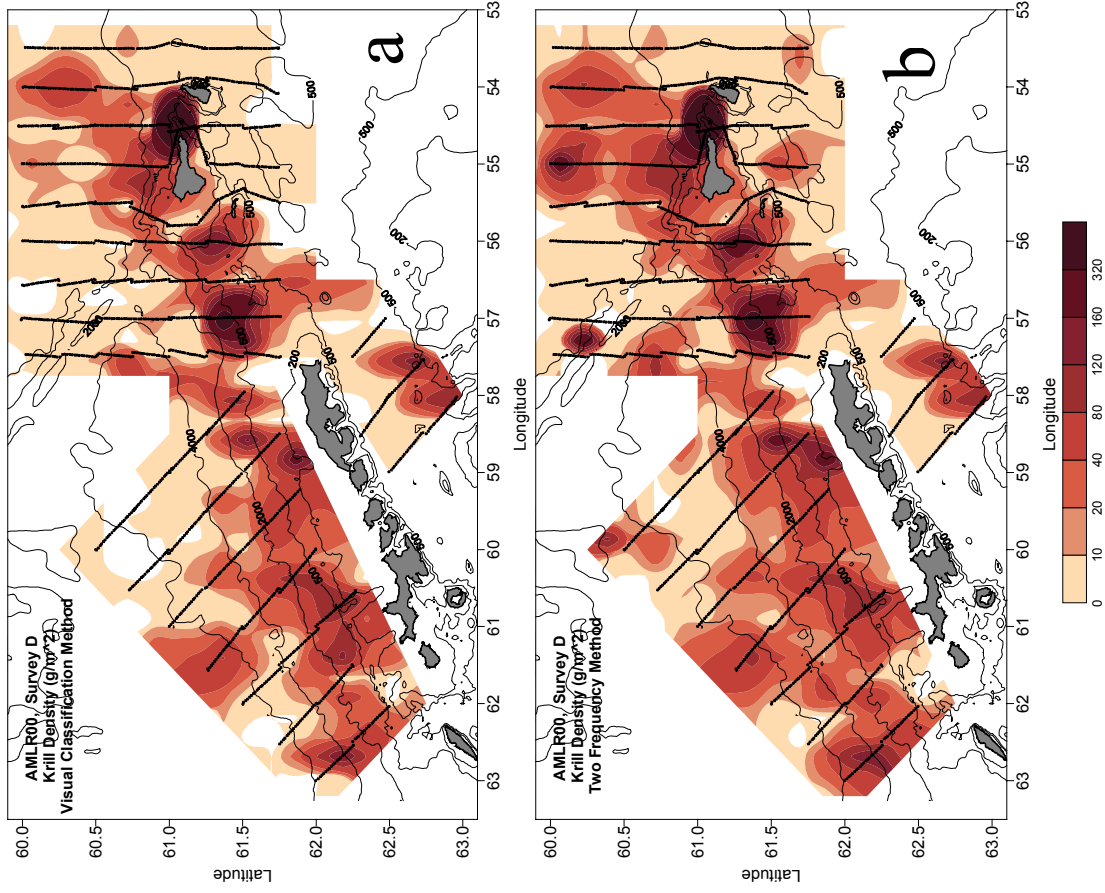


Figure 3.1 Mean krill density (g/m^2) for Survey D at 120 kHz as determined using the visual classification method (a) and the two-frequency method (b).

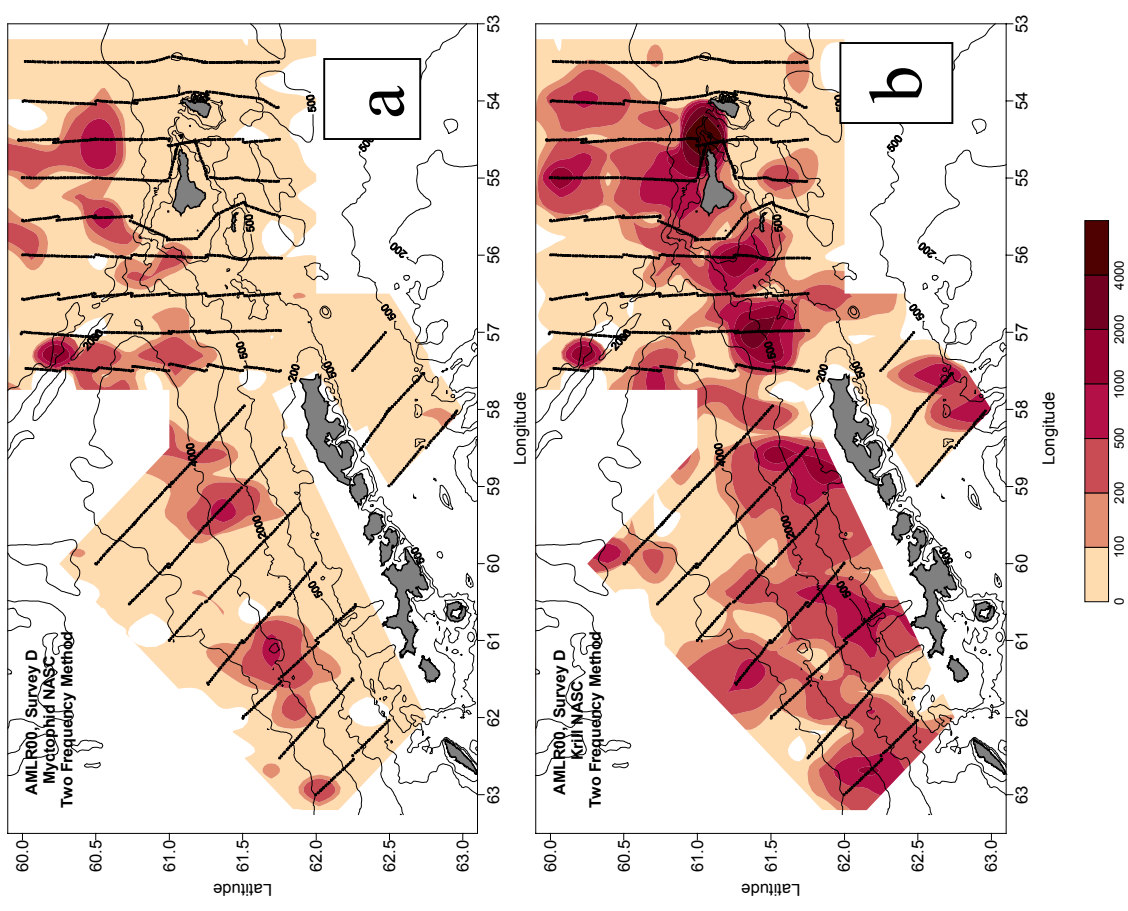


Figure 3.2 Integrated nautical area scattering coefficient (NASC $\text{m}^2/\text{n. mile}^2$) for myctophids (a) and krill (b) at 120 kHz.

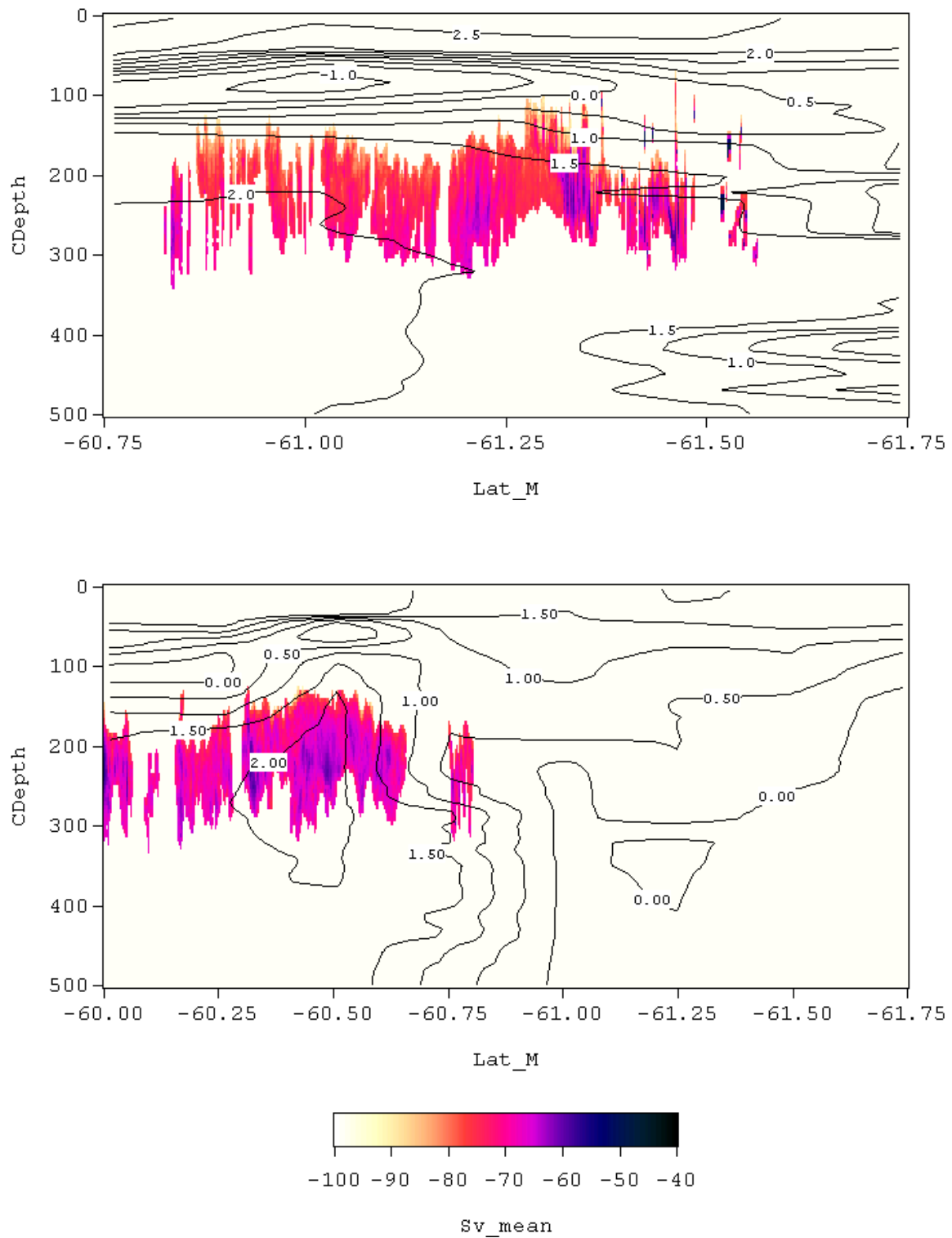


Figure 3.3 Integrated myctophid backscattering volume for Elephant Island area transect 7 (upper image) and West area transect 6 (lower image) and corresponding temperature.

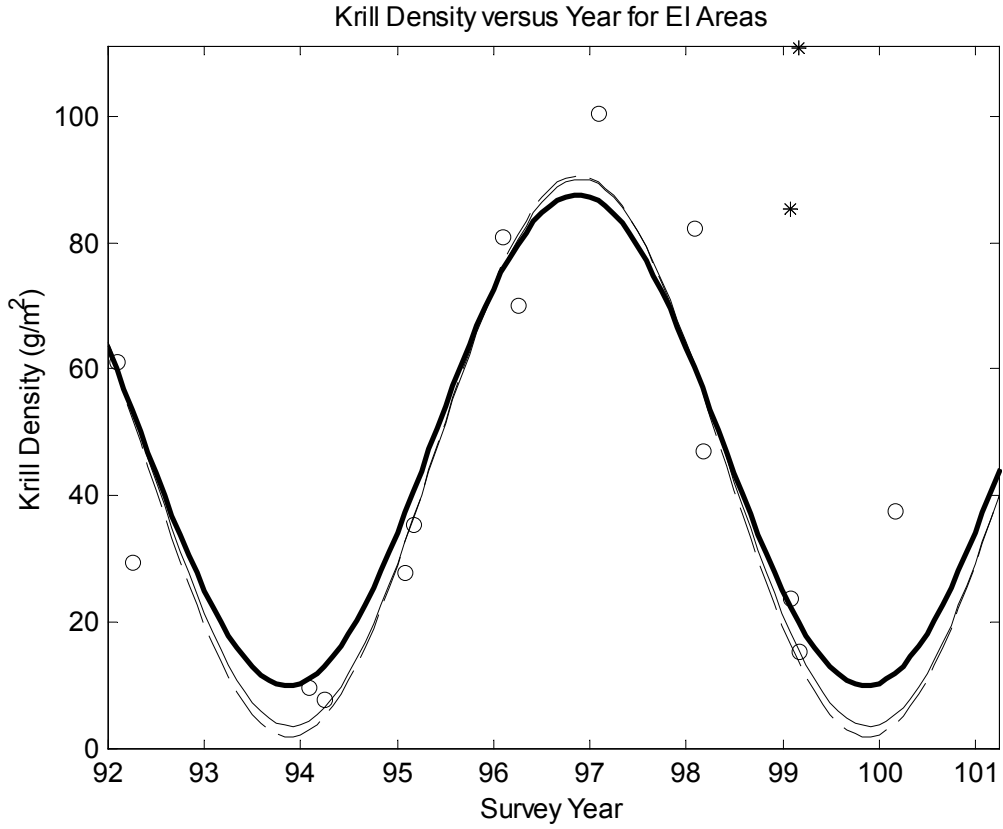


Figure 3.4 Times series of krill density in the Elephant Island area from austral summer 1991/92 to 1999/2000. The curves were fitted according to $\rho(t) = A + B \cos\left(\frac{2\pi t}{6 \text{ yrs}} + \phi_1\right)$ where t is time (years) and A is the mean values of the series and B and ϕ_1 are the amplitude (g/m^2) and the phase (radians) of the 6-year cyclical component. The thick solid line represents the curve fitted to the 1992-2000 data; the thin solid line represents the curve fitted to the 1992-1999 data; the dashed line represents the curve fitted to the 1992-1998 data. From 1992 to 1998, krill biomass estimates were obtained using total volume backscattering. For 1999, circles indicate krill biomass density estimates as determined by visual classification of krill and asterisks indicate krill biomass density estimates assuming all volume backscattering is from krill. For 2000, circles indicate krill biomass density estimates determined by the two-frequency method.